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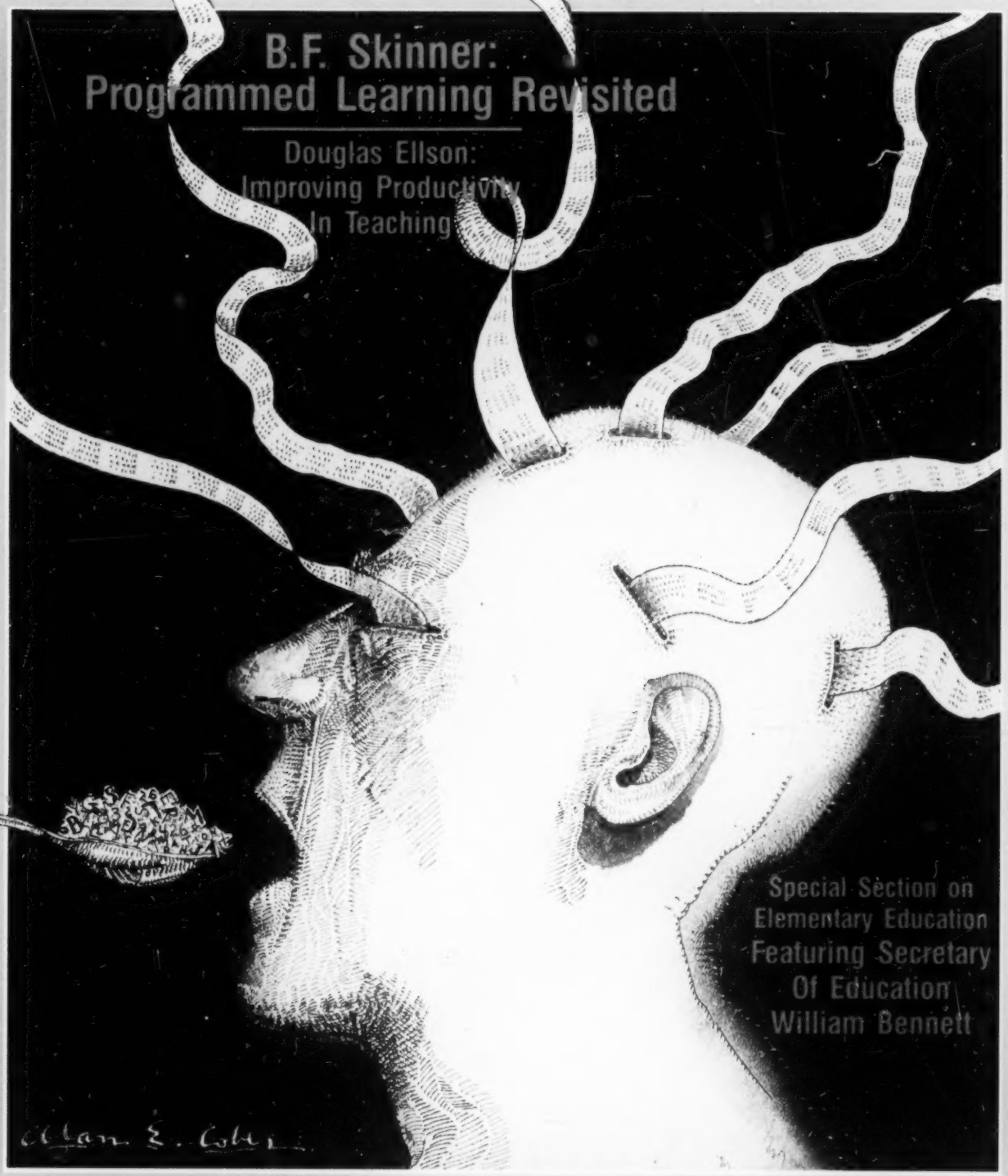
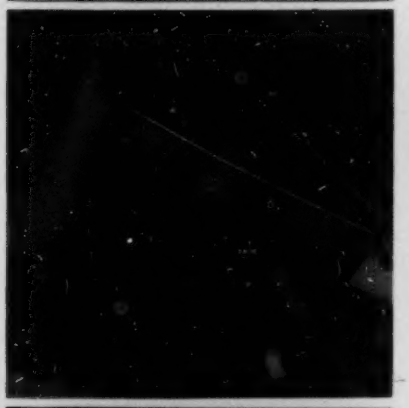


B.F. Skinner: Programmed Learning Revisited

Douglas Ellson: Improving Productivity In Teaching

Special Section on Elementary Education Featuring Secretary Of Education William Bennett



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Improving Productivity In Teaching

BY DOUGLAS ELLSON

The productivity of teaching can be improved, and research that has already been performed points the way, says Mr. Ellson in this important article. He summarizes 75 research studies – largely ignored by school and university establishments – that have the potential to change our practice.

THE NATIONAL Commission on Excellence in Education charged in 1983 that the U.S. educational system is less productive today than it was yesterday and that other industrialized nations have outstripped us in educational productivity.

The commission proposed five general solutions for this and other problems of education. But there were two important omissions from the commission's list. There was no recommendation concerning the *how* of teaching – i.e., the methods, techniques, or management of teaching – and there was scarcely any mention of the potential contribution of research and development to the improvement of teaching. These omissions would perhaps be justified if it were true that the only way to improve teaching is to improve the teachers by such administrative means as improving their salaries, selection, training, morale, and so on. But that is *not* true.

I have collected 75 research studies – largely ignored by school and university establishments – that report great differences in one or more quantitative indices of teaching productivity when two methods of teaching and/or two management systems are compared. In each comparison of two techniques, the common dependent variable is relative productivity or cost, i.e., the ratio of the effects of an experimental treatment and a comparison treatment that provides a baseline. Each study reports at least one difference in teaching productivity – teaching effectiveness, cost, efficiency, or cost-effectiveness – large enough to be educationally significant. To simplify and objectify the search process, I defined "large enough" as an improvement of 100% or more, i.e., as a difference represented by a relative productivity ratio (RPR) of 2.0 or more (the RPR ≥ 2 criterion). The 75 papers evaluate a total of 125 teaching techniques that satisfied the RPR ≥ 2 criterion for one or more indices of productivity.

DOUGLAS ELLSON is professor emeritus of psychology, Indiana University, Bloomington. *This article is an abridged version of a monograph,* Improving the Productivity of Teaching: 125 Exhibits, *to be published by the PDK Center on Evaluation, Development, and Research.* *The author wishes to thank Karen Klein, John McGrew, and Holly Arpan for their contributions.*

THE CATEGORIES

In *Improving the Productivity of Teaching: 125 Exhibits*, a monograph to be published in the coming months by the Phi Delta Kappa Center on Evaluation, Development, and Research, I have systematically annotated 125 instances of teaching techniques that satisfied the RPR ≥ 2 criterion, grouping them in eight categories that reflect practical, technological, and instructional management characteristics. Of these, five represent variants of conventional instruction and three represent variants of programmed instruction.

Of 32 examples (26% of the total in the collection) of conventional instruction that satisfied the RPR ≥ 2 criterion, eight were examples of conventional teaching. In five of the eight cases, the conventional teaching procedure satisfied the criterion in one or more comparisons with another conventional teaching procedure, usually a control procedure. In one case the criterion was satisfied in comparison with an experimental variant of conventional teaching, and in two cases in comparison with a form of programmed learning.

The remaining 24 cases of conventional instruction that satisfied the RPR ≥ 2 criterion were experimental variants of four types.

- In eight examples, the defining common feature was a major augmentation of conventional teaching. The augmentation consisted of the addition or elaboration of a number of components of conventional teaching, made possible by the provision of special funds, personnel, teaching materials, physical facilities, and so on, that are not ordinarily available in public schools.
- In seven procedures, conventional

teaching was supplemented with conventional teacher-directed tutoring conducted by students or nonprofessional personnel.

• Seven other procedures that met the criterion specified only special characteristics of the content that was taught.

• Finally, there were two relatively simple modifications of conventional teaching procedures. One of these[1] suggests a potential contribution to the art of teaching defined narrowly as the personal hands-on skill of a teacher. The other, Karnes' Community Integrated Procedure,[2] is perhaps better described as a contribution to the art of school administration. The interventions that made use of modifications of conventional teaching procedures and of the special characteristics of content, as well as some of the instances of nonprofessional tutoring, are distinguished from the augmentations of conventional teaching because they do not ordinarily require additional resources or paid personnel.

The remaining 93 examples (74% of the total in the collection) may be described as *non*conventional techniques in the sense that none are in common use in general education. All are products of a relatively new subprofession of education – namely, instructional systems design – that uses several relatively new psychotechnologies of teaching. In many cases, these techniques also make use of one or more physical technologies of education (e.g., print, broadcasting, audiovisual equipment, teaching machines, training devices, and computers) as teaching media.

Forty-three of the nonconventional cases are examples of programmed learning, a highly structured self-instructional psychotechnology of teaching that is often combined with physical forms of educational technology. Twenty-nine cases are examples of a more recently developed form of programmed instruction, programmed teaching. In this technology the teaching or tutoring activities of teachers – usually nonprofessionals – are ordinarily specified in detail in printed instructions (programs similar in function to the instructions that are an integral part of the programs given to the learners in programmed learning). Since the pupils are not required to read the instructions, programmed teaching is ordinarily better adapted than programmed learning to the teaching of beginning reading, and for this and other reasons it is better suited to the teaching of young children.

Twenty-one cases (17%) are examples of performance-based instruction or performance-based instructional design. These two closely related techniques, also developed by instructional designers, make use of explicit (as opposed to intuitive) information derived from comparisons of pupil performance with equally explicit instructional objectives. In performance-based instruction, this information, obtained in the process of instruction, is used immediately within the classroom as the primary basis for instructional decisions. In performance-based instructional design, similar information is obtained, but it is applied to the planning, design, and improvement of subsequent instruction.

The total number of comparisons in the collection that satisfy the RPR≥2 criterion is more than 500, averaging approximately four (different indices of productivity) for each exhibit. Of these, some 150 compared two procedures of the same general type, e.g., two conventional or two nonconventional procedures. In most of these, the difference in productivity favored the experimental rather than the control treatment. It is notable that in the remainder – some 350 comparisons of an example of programmed instruction with a conventional control – less than 5% favored the latter.

"I march to a different drummer . . . a dumb drummer."

Conventional teaching is a generic name for teaching procedures that are generally acceptable and in common use. Because of the practice, common in reports of educational research, of omitting a description of or even a name for the method used to teach control or baseline groups, the generic term must remain essentially undefined. It is not a single method, of course; it is many. These methods differ from one another not only in subject and level taught but in characteristics of the community; characteristics or assumed characteristics of the pupils taught; characteristics of the teacher (with regard to background, training, and personality); and many other factors.

For purposes of this review, it will be useful to identify one characteristic that seems to be common to all forms of conventional teaching; it also distinguishes them from the less-conventional, chiefly programmed forms of instruction that are also part of the collection. Currently, conventional methods of teaching are teacher-centered to a very high degree. Most of the methods I classify as nonconventional are teacher-centered only to the extent that the teacher, rather than an administrator or the public, makes the very important decision to use or not to use them and that the teacher implements or supervises their use and serves as troubleshooter.

In conventional forms of instruction the teacher – and, in the case of conventional tutoring, the tutor – is almost entirely responsible for determining how the teaching is done. To a lesser extent, the teacher or tutor is responsible for choosing texts and other teaching materials and for deciding what is to be taught from or with them – that is, for choosing curricular and instructional objectives. In the forms of instruction that I have identified as nonconventional – namely, programmed learning, programmed teaching and tutoring, and, to a lesser extent, partially programmed

instruction – detailed decisions concerning both teaching procedures and content are ordinarily made by instructional systems designers rather than by classroom teachers.

The four categories of conventional instruction that follow may be described as variants of conventional teaching.

> *In conventional forms of instruction, the teacher (or the tutor) is almost entirely responsible for determining how the teaching is done.*

With a few exceptions, the experimental variants of conventional teaching in the collection are considerably more effective than the unmodified forms of conventional teaching that were chosen as control treatments.

Augmented Conventional Teaching uses complex methods that incorporate additional resources: funds, paid personnel, special equipment and teaching materials, and so on. These resources make the work of teachers who continue to use conventional methods easier. This result is achieved by increasing instructional time; by increasing individualization; by reducing class size or teaching loads; by enabling teachers to delegate teaching and nonteaching responsibilities to other teachers or to professional specialists, nonprofessional aides, or tutors; by using additional teaching materials and equipment; by modifying content; by increasing the salaries of teachers; by improving the morale, quality, or qualifications of teachers; and so on.

Basically, augmented conventional teaching is a quantitative modification of conventional teaching. It makes increased use of certain (often many) well-known components of conventional teaching that have long been assumed to improve teaching effectiveness but are not generally used because of traditionally austere school budgets.

Differences between methods of augmented conventional teaching are at least as great as their similarities. Therefore, I will characterize them individually below, chiefly by quoting descriptive phrases from their proponents.

• College-Bound Project Method.[3] Intensive instruction in mathematics and English in classes of 16-20 students, with two periods of English; programmed instruction; individual and group counseling aid in study and work habits; library skills instruction; the use of college students as educational assistants to help provide individual instruction; the use of supervisors to develop the curriculum and work closely with the teachers and educational assistants; books; rich reading experience; speakers from the fields of higher education and business; homogeneous grouping; and so on.

• Fernald Method.[4] Individualization of instruction; permissive atmosphere; broad, individual instructional program; specific learning goals established for each child to permit success in a learning task that has previously yielded consistent failure; improvement positively reinforced; nonpunitive learning environment; particular effort to exclude kinds of negative reinforcers and criticism that tend to lead to self-devaluation and feelings of incompetence; videotape recorders; videotaped play; closed-circuit television; a wide range of commercial and teacher-made materials; classrooms limited to a maximum of 19 students; a student-to-adult ratio of about 4:1; a group of mature and dedicated university students participating in familial and social interactions and in various therapeutic and educational programs far beyond those required to meet student needs and obligations.

• R-3 Program.[5] A motivational program emphasizing student readiness and learning reinforcement through individualized instruction; an individual-progress program that uses contracts based on extensive diagnostic-prescriptive information; continuous curriculum modification; parental involvement; an inservice training component; writing of performance objectives; heterogeneous grouping; extended field trips of two or three days in length; a curriculum that interrelates reading and mathematics with reinforcement through gaming and simulation; a teacher and an instructional aide assigned to a classroom of 20 students; 70% of the classroom work done in an individualized learning situation and the other 30% done in small groups of from two to seven students; regular home visitation by project staff; dinner meetings for parents, students, and program personnel.

• Montessori Method.[6] Low pupil/teacher ratios; extensive special facilities; equipment and materials designed for pre-academic curriculum; education of the senses; room for intellectual work; houses adapted for children and not for adults; complete equipment for the management of a miniature family;

"This isn't what I meant when I said I hoped you would go down in history."

pleasing artistic pictures changed from time to time; education of the motor skills; sensory education; oral and aural language education, including material referents of arithmetic as a language; and extensive specialized materials for instruction in each of the major curricular areas.

• Enriched Curriculum (Institute for Developmental Studies Program).[7] Emphasis on cognitive areas of language, perception, and concept formation, as well as on the affective area of self-concept; individualized instruction; small instructional groups; progress at a child's own pace; emphasis on inservice training; special teaching materials; a high degree of both quantity and quality of teacher supervision; home visits; parental involvement; creative dramatics; a language laboratory.

• Diagnostically Based Curriculum.[8] Individualized instruction based on evaluations made by four professional specialists who worked with the teacher in the classroom and provided diagnostically derived lesson plans; seven professional specialists as consultants; use of each teachable moment; new concepts demonstrated as well as explained; concrete reinforcement or social approbation; evaluations of individual children's performance in any activity; audiovisual aids; specially painted murals.

• Success Environment.[9] Positive behavior modification; teachers adhering to a philosophy of "ignore and praise" – that is, rewarding suitable behavior while disregarding improper conduct; throughout the first day and several days thereafter, immediate primary reinforcement (e.g., candy) paired with praise and token reinforcement, contingent on approximations of desired social conduct; during the third and fourth months intangible rewards replaced with activity reinforcers; pupils trade tokens for access to the activity room, supervised by paraprofessional aides; five academically oriented interest stations (a library station with books, magazines, and newspapers; an arts station with paints, crayons, etc.; a communication station with a language master, phonograph, and tape recorder; an exploratory station with science materials keyed to the instructional program; a games and puzzles station equipped primarily with academically related materials changed at least weekly by paraprofessional aides); carefully designed training of teachers in the theory and practice of behavior modification; an experienced behavioral management technician available at least twice weekly to assist teachers with current problems in classroom management; individual inservice training sessions on curriculum implementation conducted weekly by two curriculum coordinators.

"Frankly, aside from a little more light, I don't see what they get out of it."

If the funds were available to implement these methods on a large scale, the effectiveness of our educational system could be markedly improved.

Note the similarities between the Success Environment and the Diagnostically Based Curriculum. These are attributable, perhaps, to the participation of a common author, Boyd McCandless.

Results obtained in evaluations of these augmented methods of conventional teaching suggest that, if the funds were available to implement them on a large scale, the effectiveness of our educational system could be markedly improved. Reported results include the following:

• increases in Stanford-Binet I.Q. scores, ranging from 15 to 20 points, and, compared with conventional at-home treatments, performance on language tests increased by factors as high as 4.2;

• reduction in the number of classroom disruptions by a factor of 4.5 and, compared with conventional school instruction, Columbia Mental Maturity Scale I.Q. scores increased by factors as high as 13.8 plus grade-equivalent gains on tests of reading and mathematics achievement of 3.2 and 3.4 years respectively;

• improvement in scores on an anxiety scale by factors ranging from 2.4 to 9.0, and a sixfold increase in the proportion of students whose performance on academic achievement tests increased by one grade-equivalent or more during the year of evaluation; and

• gains in Stanford Achievement Test scores in reading, arithmetic computation, and arithmetic concepts by factors of 2.7, 6.7, and 4.7 respectively (compared with gains predicted by interpolation from national norms).

These results suggest that, in some areas of instruction, excellence can be achieved by appropriate modifications in teaching procedures. However, most of the modified procedures are quite costly. The categories that follow contain many examples of less costly alternatives that have produced comparable results. Some of these procedures – when embedded in suitable school and classroom management practices and an updated infrastructure and especially when used on a large scale – promise to cost *less than* the teaching methods now in common use.

Conventional Tutoring as a Supplement to Conventional Teaching. None of the seven examples of this category used professionally trained teachers as tutors. Otherwise, the examples of conventional tutoring in the collection are fairly representative of conventional tutoring as a classroom practice.

Within its limits, conventional tutoring is tutor-centered in the same way that conventional teaching is teacher-centered. Outside the classroom, tutors may be fully responsible for teaching objectives, teaching materials, and

methods. As conventional tutoring is ordinarily used in schools, the instructional objectives and materials are usually specified by the supervising teacher or by the school. General tutoring procedures are usually controlled by the teacher, but the tutor is not given a detailed or formal program to follow. As a consequence, tutors must improvise some or all of their teaching methods, and in some cases they may improvise teaching materials as well.

Three of the seven exhibits classified as conventional tutoring presented data on the performance of student tutors as well as tutees. The data indicate that the academic benefit for student tutors (cross-age or peer tutors) can be as great as or greater than that for the tutees.

In the Youth Teaches Youth Program, evaluated by Robert Cloward,[10] 10th- and 11th-grade students tutored fourth- and fifth-grade pupils in reading. The student tutors were given approximately 68 hours of training before and during a 26-week period of tutoring; they were also supervised by professional teachers during the tutoring. Each tutor worked after school with two tutees – one for four hours per week, the other for two. For tutees, gains in reading performance on the New York Tests of Growth in Reading were statistically significant for the four-hour group only, but the RPR (1.7) did not satisfy the criterion. For the tutors, whose reading achievement was also evaluated, the RPR equaled 2.0 for grade-equivalent gains on the Iowa Silent Reading Test and 6.4 for standard scores on the Iowa comprehension subtest.

In a small-scale study by Robert Morgan and Thomas Toy,[11] pupils from grades 8 through 12 tutored pupils from grades 2 through 5. Tutors were given much less training, less supervision, and more responsibility for technique than those in the Youth Teaches Youth Program. In this study, RPRs greater than 2.0 were reported for both tutors and tutees on reading, spelling, and arithmetic subtests of the Wide Range Achievement Test. As in the preceding example, differences in gains as indicated by the values of RPR were greater for tutors than for tutees.

In a third study,[12] in which underachieving ninth-graders tutored fourth-graders in mathematics (fractions), both tutors and tutees gained significantly more than their control groups, but only the difference for the tutees satisfied the criterion. The RPR was 2.01 for tutees; 1.97 for tutors. Four other studies in the conventional tutoring category examined data for tutees only.

Some of these procedures – especially when used on a large scale – promise to cost less than the teaching methods now in common use.

Content Modification in Conventional Teaching. Methods in this category are identified with special characteristics of *what* is taught rather than how it is taught. They are constructed by specifying the logic or organization of the subject matter or the relative emphasis given to particular content components. Teaching techniques may be left unchanged or altered in minor detail as necessary to accommodate special characteristics of content, as, for example, when the International Teaching Alphabet is substituted for the standard English alphabet in the teaching of reading. John Downing makes clear the difference between content and procedural changes: "In both the experimental and control classes the teachers have been asked not to change their normal methods of teaching but to operate their usual timetables and instructional procedures."[13]

Another clear example of content modification is L.N. Landa's Algorithmization Technique,[14] in which aspects of Russian grammar were reduced to precisely formulated rules, or "algorithms," then taught by conventional techniques. In the evaluation study, both algorithmized and standard grammar were taught traditionally. The performance of the two groups was compared on three criterion tests, with differences in favor of the experimental group, with RPRs of 5.0, 5.11, and 6.6. Landa's use of algorithmization should be contrasted with programmed instruction (below), in which teaching technique rather than content is algorithmized.

A particularly effective example of content modification is John Leland Carter's Language Stimulation Method.[15] Traditional small-group teaching methods were used to present content that is defined as "the first 40 daily lesson plans from the Peabody Language Development Kit." Content is thus loosely programmed or, in Landa's term, quasi-algorithmized, but teaching technique remains conventional, i.e., it is determined primarily by the teacher. Gains in I.Q. and psycholinguistic abilities were both markedly increased, by factors of 2.3 to 6.3. Follow-up measures of I.Q. and reading performance indicated that much of the effect of the 10-week, 33-hour exposure to the language stimulation curriculum was demonstrable six years later.

Other forms of content modification are often described as different methods, though they differ significantly only in content. Consider, for example, the basal reader and the phonics methods for teaching reading. Both are ordinarily taught by conventional techniques for teaching beginning reading, and teachers who use them ordinarily teach all the traditional knowledge and skill components of reading: letter names, letter and letter-group sounds, oral reading, and the meaning of words and sentences. The methods differ chiefly in the relative emphasis given to meaning and to grapheme-phoneme rules and to the order in which content components are presented.

Procedural Modifications of Conventional Teaching. A broad definition of procedural modifications of conventional teaching would include almost all the other categories of conventional instruction; the exceptions are conventional teaching and, perhaps, content modification. Programmed learning and programmed teaching are also procedural modifications.

To avoid this overlap, I have defined procedural modifications narrowly, as a relatively simple and conventional change in a teacher's skill or practice. Surprisingly, this definition included only two examples, and, strictly speaking, only one of these qualifies as a modification of teaching practice. One

example is reported in Robert Rosenthal and Lenore Jacobson's paper.[16] This study is unorthodox, and its method could not be applied without radical change; but its results and their implications are clearly of notable educational significance.

The experimental and control subjects in this study – some 620 pupils in grades 1 through 6 in 17 classrooms averaging 36 pupils each – were given appropriate forms of a standardized, relatively nonverbal measure of intelligence: Flanagan's Test of General Ability. However, the researchers told the teachers it was the "Harvard Test of Inflected Acquisition." The teachers were later given the names of approximately 20% of the children in their respective classes and led to believe the false proposition that the scores of these pupils on this "test for 'intellectual blooming' indicated that they would show unusual intellectual gains during the academic year." Actually, the children who were named constituted the experimental group (before attrition due to turnover) and had been chosen randomly from the pretested group (the entire school population). Thus, by implication, the teachers were led to believe the true proposition that the unnamed 80% (who constituted the control group) were not expected to make unusual intellectual gains.

After eight months of instruction by teachers so indoctrinated, the children were retested. Differences in I.Q. gains for the experimental and control groups, which the authors of the study attributed to "teachers' expectations," were statistically significant for the first and second grades and for all grades combined; mean gains for the first- and second-grade experimental groups were 27.4 and 16.2 I.Q. points respectively. When these gains were compared with gains for the control group, the corresponding RPRs were 2.28 and 2.36.

Considered as an evaluation of teaching methods, this study is unique. The teaching method is not specified for either the experimental or the control group. All that is known with reasonable certainty is that the teaching methods used for members of the two groups were different, and even this must be inferred from other information, including the experimental and control treatments of the teachers and their effects on the performance of the pupils.

Despite these "defects," however, the study provides indirect, but convincing, evidence that variations in teaching practice can produce significant differences in pupils' learning. By demonstrating some of the consequences when teachers hold optimistic or pessimistic views of the learning potential of their pupils, this study indicates that a teacher's attitude can be an important determinant of a pupil's performance. This evidence may be criticized, but it should not be ignored by those concerned with the improvement of teaching.*

The second example of procedural modifications of conventional teaching is the Community Integrated Procedure evaluated by Karnes.[17] Disadvantaged children were taught conventionally in socioeconomically integrated classes. "Presence of an advanced peer language model" was assumed to be the "central" experimental variable. Four RPRs, ranging from 2.06 to 8.00, satisfied the criterion that the RPR must be greater than 2. This example is perhaps better described as "miscellaneous" or as an administrative procedure than as a modification of a teaching procedure.

Programmed Learning. Broadly defined, programmed learning is a form of self-instruction in which student interactions with teaching materials (e.g., samples of the natural world or transformations of it such as those found in laboratories, shops, pictures, books, computers, and human behavior) are prescribed by detailed instructions or "programs" designed to produce or facilitate learning. The design of the program and the selection or design of the teaching materials may be governed by scientific principles of learning, by other knowledge or principles, by the art of teaching, by instructional objectives, or by any combination of these.

In practice, however, programmed learning is defined more narrowly. The term "programmed learning" commonly refers to relatively simply structured forms of self-instruction, first proposed systematically by B.F. Skinner,[18] in which procedures specified in the programs are based primarily on the concepts of positive reinforcement, operant conditioning, and informational feedback.

Programmed learning can be seen to have much in common with the recitation method, a teaching procedure widely used in the conventional classroom setting.

In these programs, though it is not required by these principles, complex or extended subject matter is ordinarily reduced to a sequence of small units or frames, each of which poses a problem that represents an explicitly defined instructional objective (e.g., a question to be answered or some other task to be performed) and provides informational feedback that enables a learner to evaluate the adequacy of his or her response in relation to the objective. If the learner judges his or her response to be adequate, this feedback is assumed to provide reinforcement; if not, the feedback presumably facilitates the formation of a better response to similar or different subsequent frames or other test situations. Described in these relatively nontheoretical terms, programmed learning can be seen to have much in common with the recitation method, a teaching procedure widely used in conventional classrooms.

Insofar as the instructions that the student follows and the information that the student is given after responding are communicated in print, the use of programmed learning is essentially limited to pupils who can read. For this reason, programmed learning is seldom used to teach beginning reading. Experience gained in the 50 years since programmed learning was first developed suggests that it may be thought of as a special form of self-instruction that en-

*Because of the unorthodox nature and the potential importance of the Rosenthal/Jacobson study, it should be added that, while several studies using similar procedures have obtained similar results, others have not. Further research is required to determine the conditions necessary to produce this expectancy effect – and perhaps to use it to benefit pupils.

ables those who can read, but are not fully literate, to learn more easily from print. As a means of instruction it is generally more tolerant of inadequate literacy than are most conventional books.

Programmed learning was first systematically developed for instructional purposes between 1925 and 1950. A catalog listing more than 2,000 programs, chiefly of U.S. and British origin, and representing a wide variety of academic and vocational curricular areas, from preprimary to university levels, was published in 1972.[19] Clearly, these programs are not widely used in U.S. schools. However, programmed learning has been adopted as a major technique for industrial and military training, perhaps because highly specific curricular requirements, a shortage of teachers with suitable technical training, irregular enrollment times, and other practical constraints rule out many conventional solutions to the problems posed by training.

The Open University of Great Britain[20] provides an exceptional but important example of the academic application of programmed learning. The programmed learning technology used by the Open University satisfies the narrow definition of programmed learning, but it employs very large rather than small frames and in other ways more closely approximates conventional teaching procedures. The basic programmed instruction is supplemented with several conventional teaching procedures – lectures, demonstrations, laboratories, and tutoring – that provide the student with a variety of experiences and opportunities to practice skills not easily acquired exclusively from books, programmed or unprogrammed. The Open University is a full-scale production model of a system for general education at the university level that uses programmed learning from books for approximately 85% of a student's instructional time. Simultaneously, it is an experiment that provides a large-scale evaluation of that system. Instituted in 1971 with about 25,000 students, the Open University has since more than tripled its initial enrollment, and its success is further certified by the organization of other universities on similar plans in other countries.

"I usually stay home alone after school. I have Mom's work number, and she has mine."

The Open University of Great Britain provides an exceptional but important example of the academic application of programmed learning.

The curriculum of the Open University is as varied as that of most British universities, but its students are more varied, ranging from the unemployed to those who are confined for various reasons (including prisoners). Many of these students would not have been admitted by other British universities. However, the graduates of the Open University are judged to be the equivalent of graduates of other British universities and are accepted by them as graduate students. Costs per student to the British government, which funds the university, are approximately one-third those for other British universities, and costs to the student are approximately one-fifth of student costs at other universities.

The primary teaching method of the Open University is properly classified as programmed learning, but it differs significantly in the size of the learning units. The Open University form of programmed learning might be described as a programmed library.

Apparently, the teaching effectiveness of the large-frame form of programmed learning used in the Open University plan is, so far, not equal to that reported for the more common small-frame forms. It appears to be no better than that of more conventional models of university teaching (the RPR is approximately equal to 1). However, even without improving teaching effectiveness, the Open University remains a model for economy and cost-effectiveness in university-level and, perhaps, secondary-level instruction.

Seen from the point of view of its funding agency, the cost-effectiveness of the Open University system now appears to be approximately three times that of conventional university systems. But from the point of view of the student, the more important index of relative cost-effectiveness may be the personal one – the ratio of teaching effectiveness to personal cost – which for the Open University system has a value of 5. It is this ratio that determines whether more students will obtain a university education.

Programmed Teaching. Broadly defined, programmed teaching, which includes programmed group teaching and programmed tutoring, is a method of teaching in which the interactions of teacher, pupil, and teaching materials are specified in detail. Content is specified by tightly prescribed materials and content programs; teaching procedures are specified by complete and unambiguous operational programs. Instructions are presented in printed form to a teacher or tutor, who relays them orally to pupils.

To one who observes programmed teaching in practice and does not know that the teacher or tutor is following a tightly structured program, teacher/pupil interactions are not noticeably different from those in traditional forms of classroom recitation, nor, if the behavior being taught is complex and not primarily verbal, would they appear different from forms of the project method. But, when the programs that control the teachers' activities are examined, they are found to differ only in detail from those of programmed learning.

As in programmed learning, pro-

grams for a single frame (called an "item" in programmed teaching) typically begin with the presentation of a problem or question or a request for the pupil to perform a verbal or nonverbal task. What follows is performance-based in that it depends on the pupil's response. An acceptable response is ordinarily followed by praise from the teacher or by some other indication that the response was correct. Again as in programmed learning, an unacceptable response is followed by teaching, i.e., the presentation of information designed to facilitate a correct response to the same or related items. For a simple task, the teaching may consist of the demonstration of an acceptable response, e.g., a correct answer to a simple question; for a complex task, the teacher may demonstrate, describe, explain, or otherwise present all or parts of the task that the pupil failed to perform adequately. Finally, the pupil may be given another opportunity to perform the total task that he or she initially failed. The response to this second opportunity to respond is very likely to succeed because of the teaching that immediately preceded it. If the pupil succeeds, the success is recognized or rewarded; if not, the failure is ordinarily ignored and the program proceeds to the next item. This last procedure maximizes the opportunities for success and reinforcement.

One of the more useful functions of programmed teaching is to enable those who lack special training in teaching to teach well. If the teacher or tutor is not expected to be an expert in the subject matter to be taught, the program can be designed so that the necessary knowledge is carried by the teaching materials.

One of the first programmed teaching programs to satisfy the RPR $\geq$ 2 criterion, the Bell System First Aid and Personal Safety Courses,[21] was designed to improve an existing course ordinarily taught by persons who were qualified in first aid but not in teaching. In evaluating this course, the objectives of both experimental and control courses were defined as the ability to meet the Red Cross requirements for the standard first-aid certificate. The mean gain on a criterion test by pupils taught in the programmed course was nearly five times that for the conventionally taught control group (RPR=4.74); there was no overlap between gain scores for the two groups. The 10-hour instructional time for the conventional course was reduced by 25% (RPR=1.33), giving an efficiency ratio of 6.30. As administered to employees, the 10-hour course required two days, the 7.5-hour programmed course just one day; as a result, instructional costs were reduced by almost 50%.

If the teachers for whom a programmed teaching course is designed are not trained in the subject matter to be taught, the course may be designed so that necessary subject-matter information can be obtained from an appropriately designed text, from more conventional books, or from other teaching materials. In that case, the primary function of the programmed teacher or tutor may be little more than the management of pupil interactions with teaching materials.

Both programmed group teaching and programmed tutoring have been used successfully to teach reading skills and other academic subjects at the secondary and adult levels. But most applications have been directed toward preschool through third-grade levels, at which children may not be sufficiently literate or self-disciplined for programmed learning.

Examples of widely different forms of programmed tutoring that satisfied the RPR $\geq$ 2 criterion include Alan Hofmeister's Telepac Programs,[22] which enable handicapped children to be taught basic survival skills by their parents at home, and Peter Rosenbaum's Peer-Mediated Instruction Techniques,[23] which have been used to teach English to adults, to enable third-graders to teach one another to spell, and to enable secondary school students to teach one another remedial reading and mathematics.

An outstanding example of programmed group teaching is Carl Bereiter and Siegfried Engelmann's Direct Instruction Method,[24] first evaluated at the preschool and first-grade levels with disadvantaged children. In comparisons with several other methods, this procedure satisfied the RPR $\geq$ 2 criterion for gains in Stanford Binet I.Q. scores and California Achievement Test scores in reading and mathematics. In a later national study,[25] in which 13 teaching techniques developed by leading educators were compared, the Direct Instruction Method produced substantially higher average effects than any other model evaluated. Although it was classified (by content) as a basic-area model by Project Follow Through analysts, in overall ranking of the 13 methods on multiple measures in the basic, cognitive, and affective areas, Direct Instruction placed first in all three areas.

Performance-Based Instruction and Design. Performance-based instruction and performance-based instructional design are two applications of a very basic principle of instruction: namely, that what is taught and how it is taught should be based on comparisons of pu-

"According to my own figures, I don't deserve a C- in math."

pil performance with instructional objectives.

Performance-based instruction is a general term referring to any form of teaching in which the activities of the teacher or learner during a unit of instruction are based on information derived from individualized "diagnoses," that is, from comparisons of instructional objectives and pupil performance made during the same unit of instruction. The "teacher" may be a person (including, in the case of self-instruction, the learner) or a mechanism such as a book, a teaching machine, or a computer. The performance information is obtained from the responses of pupils to test situations, such as frames or test items, that are integral parts of the instructional process rather than separate formal tests. The instructional decisions that are made on the basis of the comparison of performance with objectives are intended to increase the likelihood of agreement between performance and objectives.

Some of the most obvious examples of performance-based instruction are the procedures of programmed learning and programmed teaching, as narrowly defined earlier. In these techniques, a learner's response to a frame or item is ordinarily followed by reinforcement if the response is acceptable or by the presentation of remedial information if it is not. Both treatments are designed to increase the likelihood of appropriate responses to the same or similar test situations in the future.

In addition to the fully programmed forms of instruction just mentioned, a third form of performance-based instruction, analyzed in some detail by Taylor and his colleagues,[26] is a partially programmed form that Taylor calls "performance-oriented instruction." In this technique, the program that the teacher and pupil follow consists of a detailed statement of instructional objectives, supplemented by additional instructions to the teacher to base instructional decisions and procedures on test situations improvised or chosen to represent each objective. For the benefit of underqualified teachers, this minimum may be further supplemented by other information.

Performance-based instruction does not include such teaching practices as drills and lectures given from a written text, which involve teacher and pupil activities that are not contingent upon in-course pupil performance. However, insofar as the form or content of these techniques is determined by instructional objectives, they may be described as *objectives*-based instruction.

From a social point of view, one of the major virtues of fully programmed performance-based instruction is that it can provide a remedy for many of the defects of tests, false teacher expectancies, and other sources of bias, such as stereotyping and associated cultural and racial prejudices. Instructional programs that individualize treatments on the basis of pupil performance alone are difficult to bias on the basis of less-relevant pupil characteristics.

Unprogrammed performance-based instruction is best suited for use by well-qualified teachers – those competent to make appropriate in-course instructional decisions quickly. In fully programmed techniques such as programmed learning and programmed teaching, on the other hand, essentially all important instructional decisions concerning how and what to teach are programmed in detail in advance, so that these techniques are better adapted for use by nonprofessionals or otherwise unqualified or underqualified teachers.

Both performance-based instruction and performance-based instructional design depend for their choice of procedures on information obtained by comparing pupil performance with instructional objectives. But in performance-based instructional design the information concerning pupil performance is obtained in advance. It is not applied immediately to make decisions in an ongoing teaching process. Instead, information obtained in one tryout of a particular teaching procedure with one group of pupils is used as the basis for revising the design of that procedure for the group, not for the individual, and the effectiveness of the revised technique is evaluated in a subsequent tryout. This process of revision and refinement may be repeated indefinitely, or it may be terminated when a design is found that consistently produces an acceptable match between pupil performance and instructional objectives.

In conventional instruction, many variants of performance-based instructional design have been developed implicitly for particular conditions and purposes. In those cases, performance-based instructional design is likely to appear only in abbreviated, informal, or intuitive forms.

Taylor and his colleagues[27] have reported evaluation data for applications of what they call "performance-oriented instruction" to 16 subjects or courses in a military training curriculum. Of these, 15 satisfied the RPR ≥ 2 criterion. These results, obtained in one of the earliest large-scale applications of performance-based instructional design, represent one of the more notable achievements in the history of instructional systems design technology. The results reported for this research and development have had a significant effect on technical training in the U.S. military services. With the publication in 1975 of a six-volume training manual for instructional designers, titled *Interservice Procedures for Instructional Systems Development*,[28] the use of performance-based instructional design to improve the quality and productivity of instruction became standard practice in *all* four military services. General education has not followed a similar path.

One of the more useful functions of programmed teaching is to enable those who lack special training in teaching to teach well.

In his *Taxonomy of Educational Objectives: Cognitive Domain*, Benjamin Bloom[29] identified several of the key principles necessary for translation from the language of training to that of academic education. First, he described academic test items and examination questions as illustrations of educational objectives; second, he called most of

these illustrations examples of intellectual skills rather than knowledge.

James Sherrill[30] applied performance-based instructional design during 16 successive presentations of a relatively conventional nine-week training course in military court reporting. Instructors were qualified by experience and training as military court reporters but had no prior professional qualifications as teachers. Sherrill described his procedure as follows:

> The continual formal evaluation took the form of, class after class, course supervisor and the instructors reviewing the results of the [criterion] test, identifying those items most frequently missed, and adjusting their next presentation . . . in hopes of reducing the miss rates of the scorable test items.

Improvement in student performance in successive classes was progressive but irregular. Using the performance of the first class as a baseline, the RPR ≥ 2 criterion was satisfied by the fourth class and approximately two years later by the 15th and 16th classes of students with RPRs of 2.2, 2.56, and 6.25 respectively.

Another example of performance-based instructional design is of special interest because of its successful application to academic instruction in a public school setting. In Ralph Melaragno's study,[31] reading performance of first-, second-, and third-grade pupils in one school was scored on standardized tests annually for a five-year period during which conventional teaching of reading was supplemented by conventional tutoring. During this period both performance-based instruction and performance-based instructional design were applied continuously to improve instruction. Melaragno summarized his procedures as follows:

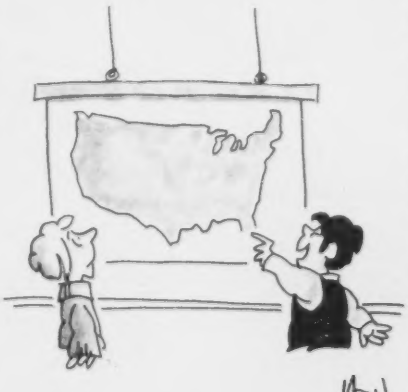
> The reading instruction used is objectives-based; it contains clearly specified instructional objectives along with materials and procedures designed to enable students to achieve the objectives. An integral part of such objectives-based instruction is the incorporation of frequent testing procedures that indicate to a teacher which objectives a student has mastered and which skills require further instruction. . . .
>
> All aspects of the school – instructional programs and support programs – are monitored by means of a program evaluation conducted every 10 weeks. This monitoring system provides information concerning progress toward objectives and ratings of effectiveness of program elements. It yields information on strengths and deficiencies so that staff involvement, planning, and decision-making can be carried out accurately and efficiently. Detailed data are collected on each student's progress; modifications to the total program and allocation of resources are made whenever the monitoring system indicates the need.

Overall, Melaragno's data indicated that year-to-year improvements in pupil performance were large, relatively continuous, and cumulative. The RPR ≥ 2 criterion was satisfied in 15 comparisons.

Two other examples in the collection of studies[32] used experimental designs similar to those of Sherrill and Melaragno (successive applications of the "same" teaching procedure) and reported improvement similar to theirs. Context information suggests that some form of performance-based instructional design was used, but since no explicit reference was made to comparisons of objectives and performance, credit for the improvement should perhaps be given to experience – an implicit or covert form of performance-based design.

COSTS AND COST-EFFECTIVENESS

Costs per se are mentioned in only two studies in the collection,[33] both of which evaluated full-scale working educational systems rather than teaching methods. In both cases, large reductions in costs were achieved with no evidence of reduction in the quality of instruction and with some indication of other benefits. Both studies report programmed instruction as the primary instructional technique. In one case, university students learned primarily at home, using programmed learning. In the other, a combination of programmed teaching and programmed learning was used for elementary-level instruction within a radically new school organization and management system. In both cases, performance-based instructional design played a prominent role in the development of teaching procedures and materials. The Open University system described above increased the cost-effectiveness of university education by a factor of three and improved the personal cost-effectiveness to students by a factor of five.



"Take a close look, and you'll see conclusive proof of my theory that Presidents are named after cities."

The IMPACT system (Instructional Management by Parents, Community, and Teachers) for elementary instruction was developed experimentally but on a relatively large scale in the Philippines.[34] With the exception of art, music, and a few nonacademic subjects, which were taught conventionally by visiting teachers and community volunteers, the entire elementary curriculum was taught using the IMPACT system. In this system, first-, second-, and third-graders were taught in groups of 10 to 12 by fourth-, fifth-, and sixth-graders. These student teachers followed programmed group teaching procedures[35] adapted from the programmed tutoring techniques developed by me and my colleagues.[36] The older pupils taught themselves, individually and in spontaneously organized small groups, using a special form of programmed learning, the "module system." Each of these older pupils also spent one hour per day teaching 10 to 12 younger pupils with programmed teaching procedures.

In each of five rural schools with enrollments of approximately 200 pupils, two instructional supervisors – professional teachers with special training in the IMPACT system – were responsible for management and supervision of the instruction. Beyond supervision, an instructional supervisor did no personal teaching except to train students to participate as learners and teachers in the system and occasionally to tutor pupils

Large reductions in cost were achieved with no evidence of reduction in the quality of instruction and with some indication of other benefits.

who transferred in from conventional schools. The set of five schools using the IMPACT system was administered by a "rural coordinator/education analyst," or roving principal, responsible for both administration and overall academic supervision.

An evaluation of the teaching effectiveness of the IMPACT system, using external examiners who administered national tests that had been developed a few years earlier to evaluate conventional elementary school instruction, showed that, for all programmed subjects combined, scores for pupils from IMPACT schools were 9% higher than those from comparable conventional schools (RPR = 1.09); costs were almost exactly 50% lower (RPR = 2). Relative to the conventional teaching system used in control schools, cost-effectiveness was more than doubled (RPR = 2.18).

COST ESTIMATES

Although cost data were not given in other studies in the collection, relative costs and relative cost-effectiveness can often be estimated with some confidence from data that are routinely reported in comparative evaluation studies (see Table 1). Using only RPRs for instructional time and a knowledge of wage and salary scales for tutors and teachers, it is possible to obtain useful estimates of relative costs. Then, given an RPR for teaching effectiveness, it is possible to estimate relative cost-effectiveness and – using the common assumption that instructional costs are 80% of the total costs of an educational system – relative cost-effectiveness of the system.

For conventional tutoring and programmed tutoring, costs vary primarily with the wages paid to tutors. With unpaid tutors (e.g., students or volunteers), especially in small-scale tutoring operations, cost increases may be negligible. In that case, the RPR for cost is approximately equal to 1 and the RPR for cost-effectiveness is equal to that for teaching effectiveness. In most cases, this is also the case with content modification and procedural modification.

Although costs for methods in the category of augmented conventional teaching cannot be estimated with any confi-

TABLE 1.
Estimates of Instructional Costs

Section A: Conventional Instruction and Management Procedures

	Category	Basic Program Unit Cost	Useful Life (Years)	Program Cost per Year	Program Cost per Hour	Pupil/ Teacher Ratio	Program Cost per Pupil-Hour
CT	Conventional instruction	$25,000*	1	$25,000	$23.15	18*	$1.29
CMCT	Content-modified conventional tutoring	25,000	1	25,000	23.15	18	1.29
PMCT	Procedure-modified conventional tutoring	25,000	1	25,000	23.15	18	1.29
CtCT	Unprogrammed tutoring within conventional tutoring (unpaid tutors)	25,000	1	25,000	23.15	18	1.29
ACT	Augmented conventional tutoring	25,000+	1	25,000+	23.15+	9	2.58+
MLC	Monitored learning center	25,000	1	25,000	23.15	81	.29

Section B: Independent Study Supplements to Conventional Instruction

	Category	Basic Program Unit Cost	Useful Life (Years)	Program Cost per Year	Program Cost per Hour	Pupil/ Teacher Ratio	Program Cost per Pupil-Hour
CBB	Conventional book-based self-instruction	$ 180	3	$ 60	$ .06	1	$ .06
CT	Conventional tutoring (unpaid tutors)	0	1	0	.00	1	.00
Ct	Conventional tutoring (paid tutors, $5/hr.)	5,400	1	5,400	5.00	1	5.00
PL	Programmed self-instruction**	180	3	60	.06	1	.06
Pt	Programmed tutoring (unpaid tutors)	180	3	60	.06	1	.06
PT	Programmed tutoring (paid tutors, $5/hr.)	5,580	1,3	5,460	5.06	1	5.06
PGT	Programmed group teaching*** (unpaid teachers)	180	3	60	.06	9	<.01
CAI	Computerized programmed learning	3,680	5	736	.68	1	.68
CDI	Computerized programmed group teaching	3,850	5	770	.71	9	.08
PBID	Performance-based instructional design	0	NA	NA	NA	NA	0

*Source: U.S. Office of Education (and, in the case of unit cost, the assumption that teacher salaries represent 80% of instructional costs).
**In the Open University and IMPACT plans.
***In the IMPACT plan.

dence from the information given in reports, it is apparent that they are among the highest in the collection – so high that, despite the general effectiveness of augmented conventional teaching, these methods are probably less cost-effective than ordinary classroom instruction. They are certainly less cost-effective than many methods in other categories.

Despite the rather general assumption that one-to-one instruction is the best of all possible teaching methods, tutoring is often ignored as a possible solution to educational problems because of a second general assumption: that tutoring is the most costly of all instructional methods. Both of these assumptions derive from thinking of tutoring only in terms of the very special form of conventional tutoring used to teach the sons of British aristocrats and comparing its effectiveness and cost with the average effectiveness and per-pupil cost for conventional classroom instruction. Bertrand Russell, in *On Education*,[37] accepted both assumptions when he wrote, "However excellent might be the results of such a system, no man with a modern outlook would give it serious consideration, because it is arithmetically impossible for every child to absorb the whole time of an adult tutor."

But in particular cases, both assumptions may be questioned. The first may be questioned because of evidence indicating that some forms of tutoring are ineffective[38] and because of the complete lack of objective evidence concerning the effectiveness of the classical form of tutoring when effects of heredity, home environment, and parental influence are eliminated. The second assumption may be questioned because of evidence that tutoring, both conventional and programmed, can be done effectively by volunteers and unpaid students. The evidence provided by Peter Rosenbaum's data[39] and that of other examples in the conventional tutoring and programmed tutoring categories suggests that tutoring need cost no more than group teaching by professional teachers. Moreover, such findings show that, when tutoring is done by unpaid tutors, it can be several times as cost-effective as conventional teaching alone. Finally, cost and cost-effectiveness of tutoring, as for other methods, depend as much as or more on the management system in which the method is embedded as on the method itself.

It should be noted at this point that in some states the performance of instructional tasks by anyone other than professional teachers (though not by books or computers) is reportedly prohibited by law. If so, and if tutoring and monitoring are considered to be instructional tasks, then peer-mediated instruction, the IMPACT system, and some other forms of economy in educational systems discussed above are presumably illegal in those states.

In most of its applications, programmed learning is potentially the least costly of all the instructional methods represented in the collection. The cost, including program development costs, can be comparable to that for conventional textbooks and workbooks and is similarly affected by scale and amortization practices. As is the case for other methods, the costs of programmed learning vary with the management system in which they are used. As a supplement to conventional teaching used simply to replace conventionally written books, programmed learning can have a negligible effect on overall costs. Used routinely as a replacement for or supplement to oral instruction by professional teachers without corresponding changes in personnel tables, the effect on costs can also be negligible. However, with appropriate changes in organization, such as those in the IMPACT and Open University systems, reductions in overall instructional costs through the use of programmed learning can be large.

In most of its applications, programmed learning is potentially the least costly of all the instructional methods represented in this collection of 125 examples.

Another potential saving can be realized by using programmed learning to help solve the problem of small rural schools. This problem is basically financial and common to most small and isolated schools and school systems.

The background which prompted the state education department of Utah to use programmed instruction was the perennial problem of small rural schools with small groups of students in each class, needing more varieties or levels of subject matter than any single, or even area, school system could possibly provide. Stated

"It may be society's report card, but it has your name on it."

> simply, their needs ran far ahead of their ability to provide curricula suitable for a broad range of students. . . . A recent report . . . suggests that the problems of such small schools may exist in all but four of the 50 states.[40]

Variations of these problems are especially common in developing countries.

For similar reasons, programmed learning can also contribute to the solution of financial and manpower problems posed by the competition between schools and other institutions for the services of those competent to teach science, mathematics, and other subjects in which there is a shortage of qualified teachers. Prototypes of many of the necessary instructional programs have already been developed, and a number of these have satisfied the RPR≥2 criterion for teaching effectiveness as well as for instructional costs.

SUMMARY AND COMMENTS

This article calls attention to a collection of 125 experimental comparisons of two ways of teaching the same subject or curriculum. In each comparison included in the collection, at least one value of a quantitative index of teaching productivity – such as effectiveness, efficiency, cost, or cost-effectiveness – was reported to be at least twice as large for one way as for the other (the RPR≥2 criterion).

In 32 of these cases (26% of the total), the method that proved to be superior in the comparison may be described as a variant of conventional instruction. The remaining 93 cases (74% of the total) may be described as nonconventional instruction. Of these, 43 are examples of programmed learning, a highly structured self-instructional psychotechnology of teaching that is often combined with physical forms of educational technology. This technique is most widely used with mature students or adults. Twenty-nine are examples of a more recently developed form of programmed instruction, programmed teaching, which is better adapted for use with young children. In this technique, the teaching activities of a teacher or tutor – rather than the learning activities of the student – are programmed by means of (usually printed) instructions that are otherwise similar to those of programmed learning. Pupils taught by this technique need not be literate or know the oral language of instruction (or, for that matter, know any language). The remaining 21 examples are categorized as performance-based instruction or performance-based instructional design. Both of these categories in one way or another combine conventional and nonconventional instruction.

By changing present teaching methods, we can improve the quality of instruction by factors of two, three, or more, with no notable increase in cost.

It is useful to think of this collection of research findings as a source of material for brainstorming sessions aimed at solving educational and social problems such as those posed by the authors of *A Nation at Risk*. In such sessions, we should discover that, from the purely educational point of view, there are not one but many problems to be solved, the total number depending on the number of subjects to be taught, the levels and types of education or training to be provided for, plus many other factors requiring special treatment.

The total number of problems is large, but it is encouraging to learn from the RPR≥2 collection that many solutions are already far beyond the brainstorming stage. Many of the methods in this collection have been use-tested for practical feasibility as well as for potential productivity, and a few are available commercially. Others have survived equally stringent evaluation in large-scale field tests and are ready for commercial development and more general use-testing. A large number of promising ideas have been tested only in pilot studies, under more or less ideal conditions made possible by small-scale operations or generous research budgets. But such once-tested models are at least one step ahead of the untested ideas frequently produced by brainstorming, and they can provide useful starting points for the systematic research and development that must be undertaken if we are to achieve long-term solutions to large-scale problems of teaching productivity.

With two exceptions, no data on actual costs of the teaching methods evaluated were given in the source reports. In many cases, however, it was possible, by using information routinely provided in experimental evaluation studies and by making reasonable assumptions, to obtain useful estimates of relative cost and cost-effectiveness. These estimates indicate convincingly that, by making changes in present teaching methods, we can improve the quality of instruction indicated by academic and later real-world performance of pupils, and we can do it not by a few percentage points but by factors of two, three, or more, with no notable increase in cost. Costs can be reduced to a similar degree with no sacrifice in the effectiveness of instruction. Especially when new organization and management procedures are introduced to take advantage of the potential economy of teaching methods that facilitate delegation, *large increases in effectiveness of instruction are not at all incompatible with large reductions in cost.*

In drawing conclusions from the information I have summarized here, it is well to remember that the collection of studies was assembled in a relatively informal and unsystematic way. The collection contains many items that a critical scientist, *as scientist*, would probably reject. But as educators who are (or should be) looking to research for possible answers to practical problems, we are not acting strictly as scientists. We are acting as technologists, and in this role we cannot afford to be overcautious too soon. And, as members of the concerned public, we are in a position to ask those responsible why we are not teaching as well and as economically as the state of the art (or the technology) permits.

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"I understand you have an awfully large class this term. . . ."